AN ATTEMPT

TO DISCOVER SOME OF

THE LAWS

WHICH GOVERN

ANIMAL TORPIDITY

AND

HIBERNATION.

BY

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The works of the Supreme Architect, being stamped with the seal of his infinite perfections, cannot be exhausted by human industry.—*Spallanzani.*

We are very liable to error by drawing hasty conclusions from a few isolated facts, *as they occur in the higher grade of animals*, without availing ourselves of the phenomena of *more extensive animal existence.*—*Harlan.*

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INTRODUCTION.

Before the time of Lavoisier, Spallanzani, Tremblay, Haller and Bonnett, little was known; or if it was known, little was published upon Animal Torpidity. Between the years 1767 and 1780, the discoveries of these philosophers became more extensively known in Europe and the United States, and they caused many persons to observe the courses of nature, who had never before thought such studies worthy of pursuit.

About the beginning of the present century, the National Institute of France offered a premium for the best essay upon the hibernation of certain mammiferous animals, and it was awarded to M. J. A. Saissy, M. D. of Lyons, for a work which he published in 1808. Unfortunately for the cause of science, his experiments were confined to four animals, viz. the Bat, the Hedgehog, the Marmot and the Lerot or Dormouse. For the particulars of his researches the reader must, necessarily, be referred to the original, as I have room for the results only. The next year Mr. Reeves published, in London, his Essay upon Torpidity. He appears not to have seen Mr. Saissy's book, but he had studied Pallas, Haller, Spallanzani, Hunter, Smellie and others, and he added to their discoveries some of his own, which I shall notice as occasion requires. Soon afterwards, Mr. Foster wrote his "Observations upon the Brumal Retreat of the Swallow." From that period until the publication in the Edinburg Encyclopædia,* we observe no regular dissertation upon Torpidity; but many valuable hints had before, and have since appeared in the various periodicals of their respective days, of which I have availed my-

* Commenced in 1810, ended in 1830.

self, with the view of *posting up*, (if I may be allowed to borrow that expression,) the information upon Animal Torpidity to the present time. I shall add some few experiments of my own, made in continuation of M. Saissy's.

The object in publishing this essay, is to elicit novel and correct information upon the subject to be used in a second edition, and which will be thankfully received.

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ANIMAL TORPIDITY AND HIBERNATION.

EXPLANATION OF SOME TERMS.

Certain animals fall into a state which is called "Torpidity," from "torpeo," to benumb, and also "Lethargy," from "lethe," forgetfulness and "Argos," slow. Both these words are defined to be "a propensity to *sleep* which cannot be resisted." But the sleep of torpidity differs materially from ordinary sleep.

The animals which sink into this state are called "hibernating," from "hibernus," winter; from a supposition, prematurely made, that *that* was exclusively the season of their torpidity, and that *cold* was the only immediate cause; whereas, (as will hereafter be shown,) there are animals which become torpid from heat or drought, or owing to a deprivation of oxygen, or to enable the subjects to effect some material change in their organization.

The state, for similar reasons, has also been called "brumal," from "bruma," winter.

Torpidity is of two kinds, viz. partial and profound. The latter is when the animal functions are entirely suspended.*

It is also involuntary and voluntary; the latter is that state into which the opossum and many insects throw themselves to avoid capture.

The *place* where the animal hibernates, is called the hibernaculum.

* I define Torpidity to be "a natural. temporary, intermediate state, between life and death; into which some animals sink, owing to an excess of heat, or of cold, or of drought, or want of oxygen, or for the purpose of enabling them to effect some natural change in their form, such as developing some organ, or of making some addition to their structure;—during which state, (when it is profound,) their respiration and digestion are entirely suspended, their circulation reduced to an oscillation of the heart and its immediate vessels, (without, however, destroying the liquidity of their blood;) all sensibility and power of voluntary motion are destroyed, and the irritability of their nervous system is greatly diminished."

TABLE

OF THE ANIMALS WHICH BECOME TORPID.

1. Of the *Vertebrated* there are four classes, and two of them only, contain hibernating animals, viz: the Mammalia and Reptiles.*
   1. The class Mammalia contains nine orders, and two of them only hibernate, viz: the Carnaria and Rodentia.
      3. The order Carnaria contains three families, and they all three have hibernating animals, viz:
         1. The family Cheiropteres.
            1. Genera, Bat, Vespertillo.
         2. Family Insectivores.
            1. Genera Hedgehog. (Erinaceus.)
            2. Tenrec, Centenes,
         3. Family Carnivorous.
            1. Tribe Plantigrades.
               1. Genera, Bears, Ursus.
               2. Raccoons, Procyon.
      5. Order Gnawers, Rodentia, has twelve tribes, of which four have hibernating animals, viz:
         2. Tribe Muséides (Arctomys.)
            1. Genera Marmot, including Prairie Dog, Woodchuck, Hamster, and Loirs, including Lerot and Dormouse, and Gerbilles.
         3. Tribe Gerboisians, (Dipus.)
            Genera Jerboa, Dipus Sagitata, D. Canadensis, D. Labradorius.
         4. Tribe Arvicolians, (Arvicola.)
            Genera Water-rat, Field-mouse.
         9. Tribe, Porcupines, (Hystrix)
   3. Class Reptiles, has four orders, all of which contain hibernators.
      O. 1. Chelonians or Tortoise.
      O. 2. Saurians or Lizards.
      O. 3. Orphidians or Snakes.
      O. 4. Batrachians or Frogs.
2. Of the Moluscous, has six orders, one only has hibernating animals, viz:
   3. O. Gasteropodes, which has two families—Terrestrial and Aquatic; both which contain animals that hibernate.
3d. The Articulated contains five branches, three of which have animals that hibernate, viz:
   1st. Branch Insects, which have twelve orders, nine of which have hibernating animals, viz: Coleoptera, Orthoptera, Neuroptera, Hymenoptera, Lepidoptera, Hemiptera, Rhipiptera, Diptera and Siphonoptera.
   2d. Branch, Arachnides, which are either pulmonary or Trachean.
   The pulmonary hibernate.
   3d. Branch, Crustacea, which has nine orders, the first, or Decapodes, hibernates.
4th. The Radiated has six classes.
   1. Rotifers hibernate from drought.

* For a long time it was supposed that the *swallow* hibernated, and many curious speculations upon that subject may be found in Mr. Foster's Observations on the Brumal Retreat of the Swallow, and in the periodicals of England and the United States, published about the beginning of this century. Of the migration of fishes, Edwards observes, that "they unite in troops, and sometimes make long voyages, either to reach the sea, or mount a river, or to change a latitude. Some fish lead a sedentary life, others are always moving, and numbers of them periodically make voyages of more or less extent. At the approach of the cold season, they ordinarily approach the shores, or enter into

OF THE RESPIRATION OF TORPID ANIMALS.*

Of all the phenomena attending torpidity, the most extraordinary are those which relate to respiration.

Mr. Saissy found that the hibernating mammals which came under his observation, consumed, when they were enjoying their usual activity, a quantity of oxygen considerable enough for their volume; but *none* when *entirely torpid.*

Torpidity is not confined to animals which do not breathe freely. The bat, the bear, the marmot, and others, who breathe freely, *by lungs*, become torpid, as well as reptiles, who *force* the air into the lungs by muscular exertion; and insects, which have *no* lungs, but that receive the air required through a multitude of little tubes, or canals, communicating without and within, become torpid, not only from cold, or want of oxygen, but also occasionally from heat, or to undergo a metamorphosis.†

With mammals, it had been found that respiration does not cease *all at once*, but *gradually*, in proportion to the degree of torpidity, from the most partial to the most profound state. I have found the same to be the case with frogs.

M. Flourens says, that there are distinct degrees of torpidity, viz: imperfect, where respiration is suspended gradually, and is resumed again every two or three minutes; and, he adds, that he

rivers; and, in that way, sometimes make a long passage. Each year, about the same time, the fish of the banks become travelers, arriving in the same latitudes at regular periods; and it is believed that many of these species emigrate regularly from the north towards the south, and from the south towards the north again, in following a determined route. But, perhaps, it would be more correct to believe that *when they disappear from the shores that they retire to the great depths of the ocean.*"

Speaking of the hadock, (morues,) he says, "that *during the winter they retire to the depths of the sea.*" He also remarks, in regard to the mackerel, "that some have pretended that they pass the winter in the North Sea, &c.; but this opinion is based upon insufficient proofs, or it is probable that their migrations are more limited; *there is even reason to believe that during winter they retire into the great depths of the ocean.*" But whether sea fishes, (if they do retire to the depths of the ocean,) become torpid there, we have no means of knowing, and hence we cannot class them among hibernating animals.

A writer in the American edition of the Edinburg Encyclopædia, tit "hibernation," says, "that some river fish hibernate;" but no particulars are given. I have not, therefore, placed fishes among animals who become torpid.

* Respiration is defined to be "the act of breathing;" but "*the act of breathing*" includes the whole series of phenomena which result from the relations of the air with organized beings; forming one of the most important parts of their physiological history. The means by which this act is performed, are either *simple and general*, through the medium of any part of the animal which comes in contact with the air, but particularly the skin; or *particular and special*, as by vibratory cills, cutaneous tubercles, trachées and stigmates, gills, or lungs.

† Metamorphosis, from "meta," against, and "morphe," a form, a transfiguration, or change of shape.

has often seen it extinguished [suspended] for whole hours, while he continued to make his observation.—*Revue Encyc.* V. xi. p. 385.

M. Saissy, tells us that the consumption of oxygen diminishes in exact proportion to the debasement of the temperature of the animal.

Animals about to become torpid naturally, generally seek retirement; hiding themselves, sometimes in a cavern or hole, at others enveloping themselves in a hibernaculum. The quadrupeds draw themselves into the smallest compass; the nostrils are brought in contact with the chest, and buried in the hair or fur; bats cluster together in caves, hanging by their thumbs; moluscous animals, such as the snail, retire in their shells, closing the entrance with an operculum. Flies and spiders crawl into holes.

Some writers are of opinion, that to effect torpidity, *confined air* is required, Pallas tells of a hamster, which, when enclosed in a box filled with earth and straw, did not become torpid, although exposed to the requisite degree of cold; but which, when the box was burried in the ground, became completely lethargic. Upon being taken up he aroused, and he sank anew when buried again. And M. Reeve informs us that at Vienna, in December, 1805, he had a hamster in a cage, kept in a room where there was a fire; that he ate heartily and appeared to be in good health for several months, showing no signs of torpidity, except remaining rolled up in coarse wool and dried leaves; he came out once or twice a day for food. One cold night *he died without any apparent cause.* M. Reeve attributed it to *want of confined air.* But *I* think it quite as likely that this hamster's death was occasioned by keeping it in an *unnatural* state, viz: in a room with a fire.

However this may be, it is certain that the *light* has nothing to do with the condition, for Pallas says that his hamster was dug up in the *night* and revived; and I have often put bats and frogs into a state of profound lethargy, in broad daylight and in the open air.

But the most interesting question is, whether respiration is *entirely extinguished.*

Smellie says, that not only is the respiration much lessened, [in volume,] but that the hibernating animal has long intervals of complete repose, during which time it does not breathe at all; and that it afterwards performs a number of respirations in immediate succession; and that sometimes the function is, for a considerable time, *entirely suspended.*

M. Bingley remarks, that during its state of torpor, the bat's animal functions are so far suspended as to be scarcely susceptible; that the action of the heart and arteries become exceedingly languid, and respiration is scarcely distinguishable.—(*Memoirs of British Quadrupeds*, 1809.)

M. Reeve, (speaking of the same animal,) says that he never could discover the least motion in his flanks, when in a state of torpidity. And M. Spallanzani assures us that he could not, *with the aid of a magnifying glass*, detect any breathing.

M. Flourens, in addition to what I have above quoted as to *partial* torpidity, says, that in *perfect* lethargy the respiration is completely extinguished.—(*Revue Ency.* V. xi., p. 385.)

In another page he remarks, that he submitted several torpid animals to different mephitic gases, and found that the *total suspension* of *respiration* is a phenomenon *as incontestible* as it is curious.

M. Spallanzani introduced a bird and a rat into a receiver containing carbonic acid gas, and they died in less than a minute ; but a *torpid hamster* remained in it one hour uninjured. Torpid marmots were, by the same experimenter, subjected to the action of carbonic acid gas and hydrogen gas for hours, without injury. And four or five cubic inches of atmospheric air was not changed in its properties after torpid bats and torpid marmots had remained therein for three hours.

M. Saissy, after a series of experiments, conducted, apparently, with great skill and care, came to the following results, viz. that in the cases of the marmot, hedgehog, lerot, and bat, respiration is subordinate to the temperature of the atmosphere,—that it is short and precipitate in summer,—slow in the beginning of autumn,—almost insensible in moderate torpidity,—and *null when they are plunged into profound lethargy.* Those who are curious, particularly if they are skeptical upon this subject, are recommended to have recourse to his book and to repeat, if they have opportunities, his experiments, for the particulars of which I have here no room; they will there find the following to have been the fair results of his labors.

1st. That (as before stated) these animals, when they are enjoying their usual activity, consume a quantity of oxygen considerable enough for their volume.

2d. That this consumption diminishes in proportion to the diminution of their temperature.

3d. That they possess at all times the faculty of existing a considerable time in an air that is fit for neither combustion nor respiration, without being much fatigued.

4th. That during their torpidity, but while respiration is still visible, the consumption of oxygen is very small compared with that of their ordinary state, and

5th. That during *profound torpidity* there is no consumption of oxygen at all, and consequently *no respiration.*

To these opinions and experiments I will now add a few cases :—

The alligator hibernates with a pine or cyprus knot in his mouth, completely closing the passage to his stomach.—(*Dr. Dickerson.**)

A farmer in Selburne, Hampshire, England, in the winter of 1769, was ploughing up a dry, chalkey field, far removed from any water, when he turned out of the earth a *water-rat*,† that was curiously enclosed in a clayey hibernaculum.—(*Bingley.*)

In the month of November, 1798, in Vermont, a mouse,‡ in a torpid state, was found in the earth, enclosed in a ball of clay about the size of a goose's egg. The ground was a loomy sand which projected into a meadow, and bore no appearance of having been broken up; nor was there any communication with the external air or with the surrounding earth. The animal was removed to a warm room, where it gradually recovered, and from which it finally escaped.§

Bats have been found in an excavation, where, owing to a landslip, they must have been confined for thirty years. They were torpid, but some of them revived in a warm room and flew about.‖

Twenty or thirty frogs were found twenty feet deep in the earth, near Manchester, Vermont, where they must have been buried some hundreds of years, in a torpid state, for the ground had recently been cleared to build, and the stumps were from two to two and a half feet through. When exposed to the sun the animals revived.¶

To these I will add the very interesting account, given by M. B. Gaspard, of the snail; (an abridged translation of which will be found in the Boston Journal of Philosophy and Arts, V. i., p. 570.) He states that those animals form a soft, silky membrane across the external openings of their shells. On the internal surface of this membrane they deposit carbonate of lime, which immediately hardens like gypsum. This partition is again lined with a silky membrane. The animals then retire further into the shell, and form a second diaphragm; but this one is wholly membranous. They proceed, retiring and forming these partitions,

* From the middle of September to the first of October, the alligator of our south (says Dr. Dickerson) becomes careless of his food; about the latter end of October he selects a pine or cypress knot, with which he stops his mouth, the end extending into his throat; he then crawls into a hole under water, where he remains torpid till the blowing of the dogwood in the spring, when he re-appears and ejects this piece of wood, which by that time is rounded and smoothed.—(*Verbal account.*)

† Order Rodentia, Tribe Arvicola.

‡ Order Rodentia, Tribe Arvicola.

§ Mem. of the Acad. of A. and S., V. ii., pt. 2., p. 125.

‖ Ibid. p. 63

¶ Silli's Tour, V. xxiv.

to the number of, sometimes, six. In the *last recess*, they remain from November till May.*

M. Gaspard is of opinion, that during the whole period of their retirement, the animal powers of the snail are *entirely suspended*, with the exception of a slight susceptibility of muscular sensation; so that from five to nine months of the year, (says this natural historian,) this animal lives without motion, without heat, without food, without air, and without circulation; in a word, without the exercise of any of the animal, organic, or generative functions! In what then, (he enquires,) does its life consist, if life it may be called? He himself answers, that "it resembles that of a germ before fecundation,—or of a seed before it sprouts,—of an egg before incubation. It is rather *a capacity for life* than life itself, a capacity which is called into actual exercise, by the mild temperature of the spring."

I respectfully object to M. Gaspard's similie, for, in the animal germ and egg, there is only the *source* of growth and increase *entirely at rest;* but in torpid animals, (as we shall perceive when we come to treat of the circulation,) there still remains *a small degree of action*, which action, diminutive as it is, entitles the possessor of it to be considered as having *something* more than *a mere capacity for life.*

But to return to M. Gaspard himself; it might be supposed that *some air* could be admitted through perforations in the operculum, &c. Not so; for he says, that to ascertain whether that is the case, he preserved some of these snails for three months, under water, at the temperature of 40° to 45°; others in mercury, and others, again, in oil; he therefore felt himself justified in avering that they subsist *entirely without respiration.*

Now, what answer can be given to this evidence of *total extinction of respiration* of snails? Will it be contended that these animals subsist upon the modicum of air which remains in the deepest recesses of the shells? Even this last resort is withdrawn; for M. Gaspard concludes, by informing us that he collected this air and examined it, and that it retained its properties sufficiently to support combustion; and, of course, that it could not have been impaired by the respiration of the animals. These are the facts gleaned from natural history, and, in part, confirmed by my own experiments, in relation to the total suspension of respiration during the torpidity of animals; to what reflections do they give rise?

According to the present system of animal biology, there are but *two* states or conditions, viz: one wherein there is respiration, circulation, assimilation, and gradual waste of organism; which state

* When prevented from hibernating for several seasons, by keeping them in a warm room, they gradually waste away and finally die.

is called LIFE. And the other condition, where every part of the body, (except the bones,) enters into combination with oxygen and gradually decomposes—which is called DEATH. But, if this doctrine of the *total extinction of respiration* be correct, *then* is there a *third, and intermediate state*, which is neither *life* nor *death*, but "TORPIDITY!" "At every moment of life," says M. Liebig, "animals are *taking oxygen into their systems*, through the organs of respiration; there is *no pause while life continues.*"—*Animal Chem.* p. 12.

But with torpid animals *there is a pause;* they *cease entirely* to take in oxygen by their organs of respiration, then *they are not alive!*

But "death," says the same author, "is that condition in which *all resistance*, on the part of vital force, entirely ceases."

But with torpid animals *all resistance* of vital force has *not* entirely ceased; as we shall find when we come to examine their *circulation*—then *they are not dead!** From life to torpidity there is a material *change*, and from torpidity to death there is a material *change;* wherefore, a torpid animal is neither *alive* nor *dead!*

OF THE CIRCULATION OF TORPID ANIMALS.

As every portion of the animal body is produced and renewed from the *blood*, the next inquiry, in point of importance, into the peculiarties of these animals, involves an examination of the *circulation* of that liquid.

All writers on torpidity agree that the blood circulates *with less intensity*, in proportion to the depth of the lethargy.

A hamster has, in its natural state, and when irritated, one hundred and fifty pulsations in a minute; but when the animal sinks into torpidity, it diminishes to fifteen.—*Reeves.*

Dormice, whose pulsations, when they are active, are so numerous that they cannot easily be counted, sink to twenty, nineteen, and even to sixteen.—*Ibid.*

A snake, whose normal pulsations were thirty, diminished to eleven.—*Spallanzani.*

Toads and frogs, from thirty fell to twelve.—*Reeves.*

The last quoted author contends that the *action* of the *heart* is not entirely stopped and that the *circulation of the blood* is not entirely suspended; although he admits that it is too feeble and obscure to be always perceived.

* Torpidity is not sleep, for sleep is that condition in which *voluntary* motions only are checked to afford an accumulation of living tissues to make up for their waste during our waking hours; but during profound torpidity, *involuntary* motions also are suspended, and no such accumulation can therefore take place.

M. Saissy, on the contrary, avers that when the torpor is *profound* the *circulation* is *entirely suspended*. The vessels, he says, appear as if struck with death.

The discrepancy between these two distinguished writers will be easily understood by the intelligent observer.

M. Reeves considers the circumstance of the blood remaining *fluid*, as full proof of its *circulation;* whereas, M. Saissy, while he admits that the blood does not coagulate while it remains in the proper vessels of these animals, (as first stated by M. Spallanzani, and afterwards by M. Reeves,) contends that it is cold and *stagnant*, at least in the arteries and veins of the extremities, and the cavities of the cranium and abdomen. He acknowledges that in the thorax, one perceives "*the remains of a circulation*," or rather "*an oscillation of the heart* and the larger vessels belonging to it;" but this "*oscillation*" he does not consider to be worthy of the name of "*a circulation*."

He laid bare the femoral artery of a marmot which was torpid, and could discover *no pulse*. He tied the femoral artery and vein, but the former did not swell *above*, nor the latter *below* the ligament.

Both vessels were opened—the blood wept slowly and passively, as from a part struck with death; and we know that this it would have done from the mere elasticity of the parieties of the artery and vein, without any influence of the heart.

It is true, as he says, that the heart, the pectoral aorta, the subclavians and primitive carotids are full, but they give only 10 or 12 pulsations in a minute. He, therefore, concluded that these animals, in the state of profound torpidity, have *no circulation*. It must be recollected that the heart is the first muscle to receive and the last to lose its power of contraction. In the chick, in ova, the heart may be seen performing its functions before there is any appearance of brain or spinal marrow; and the heart of a snake, torn from its body, continued its contraction for ten or twelve hours.—*Harlan's Medical Researches*, p. 503, 556.

M. Flourens, in describing the condition, of which we have been treating, remarks, that at first there is no pulse in the arteries of the limbs; then the circulation of the whole body gradully declines, to *complete extinction*.

Now for the decision. If, by "the circulation of the blood," is meant merely that it remains in a *fluid state*, we must pronounce in favor of M. Reeves. But if by it is meant that "not only is the blood fluid, but that it *flows* from the lungs to the heart, and from the heart to every part of the body, and that it returns to the lungs again;" then must we decide in favor of M. M. Saissy and Flourens, and establish that torpid animals, *when in a state of profound lethargy, have no circulation*.

M. Saissy's experiments were confined to mammals, but I can testify that the rule is more general. The circulation of the blood of reptiles differs materially from ours; their heart has two auricles and but one ventricle. At each contraction of the heart, *a portion only* of the venous blood is sent to the lungs, while the rest is sent to and mixes with the arterial blood. In consequence of which arrangement, and of the peculiar formation of the vessels, the *head* receives pure blood, while all their posterior portion receives but a mixture of arterial and venous blood.* Besides which, the globules of the blood of reptiles are elliptical in form, and have a diameter of only $\frac{1}{45}$ to $\frac{1}{75}$ millimetres.†

The relative quantity of globules in their blood is only five or six hundredths of its whole weight; whereas, in the most perfect animals they are from fourteen to fifteen hundredths; and we know that upon the relative quantity of globules depends the *richness* of blood.‡

Moluscous animals have *white* blood, but a complicated circulating system. The heart, which has but one ventricle, and one or two auricles, sends the arterial blood to every part of the system, from which it returns through the veins to the respiratory organs. But moluscs *require a great deal of moisture*, and become torpid *from drought*, as we have already seen. According to M. Gaspard, the snail, during torpidity, is *entirely deprived of circulation.*

On the other hand, insects have *no circulation.* The blood, which is colorless, is not confined to vessels, but may be found in the interstices of their organs. It is true, that in certain parts of them, *currents*, some of them pretty *rapid*, may be detected; but there is no CIRCLE of *movement*, by which it flows from and returns back again to a particular part, as there is in the higher animals; and during profound torpidity, even *these currents are stopped.*

In the arachnides, also, the blood is white. The pulmonary arachnides have a complete circulation; the heart, which is an elongated vessel, situated upon the back of the animal, gives birth to many arteries; the blood, after having visited the extremities, goes back again, as it does in the moluscous class. When the respiration is effected by trachées, the apparatus of breathing is rudimentary; they having, in that case, a simple dorsal vessel, without veins or arteries.

In neither case, during profound torpidity, does there exist either a circulation or currents of blood, so far as I have been able to discover.

* The crocodile is an exception.

† A millimetre is the millionth part of a metre, and a metre is the ten millionth part of an arc of a meridian of three feet and eleven lines, or two hundred and ninety-six millionths of a line.

‡ See Harlan's Researches, p. 199.

OF THE DIGESTION OF TORPID ANIMALS.

Digestion consists in the natural separation of the nutritive part from the rest of food introduced into the system, and its transformation, first into *chyme* and then into *chyle*; which latter substances mixes with the blood, and is carried, by it, to every part of the organization, for its nourishment and renewal.

But during the existence of the extraordinary state about which we are treating, all the apparatus of these functions are *entirely at a stand.* The animal, as if conscious of its approaching condition, declines food.

Doctor Monroe kept a hedgehog in a room at Edinburg, without a fire, from November until March. About December, it was affected with an unusual degree of drowsiness, but it continued to eat, sparingly, until the 25th day of that month, when it sank into a state of profound lethargy. It so remained until the 8th of March following, except when occasionally roused, but it would soon return to the torpid state again. During all this time it ate nothing, drank nothing, although food was constantly kept before it.

So M. White, of Sethbourne, kept a land tortoise for forty years. During the summer months it was very voracious, but it gradually became less so towards autumn, and by the middle of November it sank into a torpid state.

There is no food of which the alligator is so fond as a dog, yet when the time of their hibernation is approaching, they evince an entire indifference to it.—*Dr. Dickerson.*

M. Saissy also informs us, that the marmot will refuse to eat, and become torpid, even while surrounded by apples, pears and nuts; and the hedgehog with flesh near him.

Nature appears to have kindly deprived these animals of the desire for food, foreseeing that they were about to loose the power to digest it.

Hunter introduced food in the stomachs of lizards about to hibernate, and upon opening them, at different periods of the state, always found the aliment *unaltered.* With some, after the season of hibernation had passed, the food was ejected, *unchanged,* (indigested.)

True, M. Bingley, in describing the torpid state of the bat, makes use of some expressions which, at first view, would appear to contradict what I have been stating. He says, that "none of the functions seem to be going on, except a very slow degree of *nutrition* and an interchange of new for old matter in the depository cells of the body."

But it is evident that this gentleman used the word "*nutrition,*" for "*absorption,*" which he considers as capable of being performed *without digestion;* for he adds, that "this last circumstance is

proved by the animal entering into the torpid state very fat and reviving excessively emaciated; from which, he says, it appears that the oil in the fatty follicles of the cellular membranes, is gradually taken up, *by the absorbent vessels*, into the languid circulation, to supply the proportionably gradual waste occasioned by the more than half-suspended action of the emunctories.

In order duly to appreciate the difference between *digestion* and *absorption*, as regards the condition of torpidity, we must remember that the first is an *act of vitality*, while the last is a mere *chemico-mechanical process*, to which Dutrochet, the discoverer of the *principle*, gave the names of *Endosmosy* and *Exosmosy*. There is therefore no impropriety in supposing that the lymphatic vessels should continue in action *during torpidity;* and it might even be expected, under certain circumstances, that they should continue to act *after death*.

It is very generally believed, among sportsmen, that if a fat rabbit is killed, and suffered to remain without extracting the entrails, that the fat will disappear. If the fact is so, is it not reasonable to suppose that the fat is *taken up by the absorbent vessels*, which, in that case, continue to act *after life is extinct;* surely, then, there would be nothing extravagant, in supposing the fat to be taken up by the *lymphatic vessels*, during a torpidity so profound that digestion is entirely suspended.

OF THE SECRETIONS OF TORPID ANIMALS.

M. Liebig is of opinion, that the secretions of bile and urine go on during the sleep of hibernating animals.—(*Animal Chem.* p. 60.

The bile is secreted by the liver,—it distils, drop by drop, from the gall-bladder (or other resorvoir) into the intestines, and its office seems to be to convert chyme into chyle. But, during hibernation, the liver is *torpid*, and the intestinal canal is entirely empty. And it must be recollected, that it is not till the blood has received the *influence of the atmosphere*, that we have any bile, urine, or saliva at all.—(*Harlan's Medical Researches.*)

The urine is composed of the superabundant nitrogen, which is contained in the arterial blood, and which is extracted by the kidneys. But the blood, (both arterial and venous,) of torpid animals, is, during the period of *profound* lethargy, entirely *stagnant*, and the kidneys are *torpid*.

But the secretion of urea, uric acid, and bile, proceeds both in man and the lower animals, when the tissues are gradually wasting from disease, and when nutrition is *utterly suspended;* and they

continue long after the body has ceased to take any food whatever.—*Simon's Animal Chem.* p. 138.

Saissy found the bile of the hibernating mammals to be *sweet*, and so I have found to be the bile of the frog.

OF THE ORGANS OF RELATION OF TORPID ANIMALS.

In a state of profound torpidity, all the organs of relation are paralyzed. According to M. Reeve, marmots, in a lethargic state, cannot be roused by an electric spark, and the shock of a Leyden-jar excited them for a short time only.

Bats, when torpid, were found to be insensible to *every kind* of *stimulus*, except heat and currents of air. Wounds inflicted upon them, and even limbs broken, gave them, apparently, no pain.

M. Spallanzani subjected some animals in a torpid state to the action of noxious gases without injuring them. But what appears to be most extraordinary, is that *they died so soon as their temperatures were raised above that at which they ordinarily breathed!*

In the year 1792, Mr. Ward, of Philadelphia, then about ten years of age, was living with his father on a farm in Gloucester County, New Jersey. One day, in the month of November, a laborer, who was cleaning out a ditch there, threw out a snapping turtle, about eleven inches in length, which was in a torpid state. He cut off its head, and buried it in the ground again, about eighteen inches below the surface. In the spring of the next year, after the grass had pretty well grown, my informant, Mr. Ward, dug up this snapping turtle, and found it *still torpid*, not dead. After being exposed to the air for a short time, it revived and crawled.

M. Saissy found that, during profound lethargy, *sensibility was null*, and that torpidity, according to its degree, always *dulled* or *annihilated* their irritability; even in cases of hibernating animals the most endowed. But he also remarked, that there is a sensible difference, in this respect, between different hibernating animals.

He further discovered, that of all agents of irritability, *galvanism* was the most potent; but for it to have effect, the zinc pole must be placed in contact with the nerves, and the copper one with the muscles. He found the heart was but little sensible to galvanism, and the stomach and intestines refractory.

OF THE ORGANS OF REPRODUCTION OF TORPID ANIMALS.

Is the action of these functions suspended?

Here is a curious question, upon which no writer has ventured an opinion.

Nature has endowed females with the power of *producing* all the parts of animal organization in greater quantity than is required to supply their own daily waste; and the superabundance is applied to reproduction. But if the function of digestion is, as I have shown, *entirely suspended* during torpidity, it would seem that the organs of reproduction have nothing whereon to operate.* Now suppose that before the animal has sunk into this state of lethargy, the operation of reproduction *had commenced;* what then is to take place? Are matters to remain in *statu quo* until the animal revives? If so, then has torpidity the amazing power of enlarging to any period, however indefinite, nature's otherwise fixed time of gestation!

My friend, Dr. Harris, of Abington, to whom I suggested this difficulty, answered, with his usual shrewdness, that nature, who is ever careful not to involve herself in contrarieties, had no doubt provided that the two conditions should not occur simultaneously. But man possesses the power of artificially plunging hibernating animals into the torpid state, and of continuing its duration at his pleasure; what then is to be the result?

Besides, Cuvier, speaking of one race of animals, viz. the bear, says that "they dig caves or construct cabins, where they pass the winter in a sleep, more or less profound, and without eating, and it is *in that retreat that the female has her young!*"†

Are the reproductive organs supported entirely by absorption?

ANATOMICAL STRUCTURE AND PHYSIOLOGY OF TORPID ANIMALS.

Is there anything in the anatomical structure or physiology of animals that become torpid, by which they can be distinguished from the rest of the animals of their respective classes, orders, tribes or genera?

This, also, is a most interesting question, and I shall endeavor to concentrate all the light which is widely distributed over natural history, and cast it upon this question

* An adult frog will live for months without food, but a young and *growing* one will die if deprived of food forty-eight to sixty hours, (my own experiments.)

† Audibon and Buckman tell us that "woodchucks remain torpid from the time the leaves fall until the grass grows in the spring. That they burrow in the ground, *where the female gives birth to her young*, and where the family *spend the winter in torpidity*." This requires explanation.

1. *The Thymus Gland.*—M. Pallas was of opinion that their thymus gland was uncommonly large; and, moreover, he remarked two glandular bodies under the throat, one of which (he says) was particularly florid.

M. Reeve also found a mass of glandular substance [where?] in a marmot.

The thymus gland (glans thymus), you know, is placed between the trachea, or windpipe, and the upper part of the sternum, or breast bone. In the fœtus of the human species it is largely developed,—in the infant state it is of a very soft consistence, and of a pink color,—in the adult it is collapsed and shrivelled. Its use is not well understood. Sir Astley Cooper, so late as 1832, venturing to *surmise* only upon the subject.—*Horner's Anat.* V. ii., 139, *and Elem. de Zool.* p. 53.

M. Flourens informs us, that at the moment the hibernating animal falls into the lethargy, the thymus is in the highest degree of enlargement, and that it collapses at the time that it awakes; and yet he tells us, that he suppressed the thymus gland of a hibernating animal, which rather *accelerated* than *retarded* the lethargy.—*Revue Ency.* V. xi., p. 385.

2 *Of the Fat of Animals which become Torpid.*—M. Pallas was, perhaps, the *first* to remark that hedgehogs, marmots, &c., became very fat during the summer, and were furnished with several omenta in the abdomen; and M. Reeve observes, that he found in the hibernating animals large portions of omentum.*

The learned Cuvier was of opinion that the office of the omentum is to keep the abdomen warm; for the reason, I suppose, that fat is a non-conductor of caloric.—XXII. *Lecon d' Anat. Comp.*

And certain it is, that the cetacea being provided with no hair or wool to retain their vital heat, have, *beneath the skin, a prodigious accumulation of fat*, which, being a non-conductor of caloric, enables them to maintain their temperature in the aquatic medium in which they live.—*See Jones' An. King.* 689.

Dr. Benjamin Rush considered it a special store house [of fat] for the wants of the system during the destitution of other aliments.—*Inquiries into the uses of the omentum*, 1809.

There are cases which give color to Dr. Rush's opinion.

Dr. Currie relates, that a man who was unable to swallow, lost one hundred pounds weight in one month. And M. Martels

* The omentum, or caul, is a membrane of various densities in different animals, which lies in front of the intestines The sides of the abdomen of mammiferous animals is lined, and its vicera is covered with this membrane. Its general name is peritonæum, and it is divided into processes, each of which is designated under a different name, such as omentum, epiploon and caul. The omentum majus, in a corpulent subject, is interspersed with a great deal of fat T. Rymer Jones says, that there is no material difference in the omenta of different mammals.—*See* p 682 and No. 775.

speaks of a pig which was buried by a land-slip when fat, and which lost, in one hundred and sixty days, one hundred and twenty pounds weight.*

But Professor Horner answers, that the inhabitants of cold countries are not better furnished with an omentum than those of the torrid zone—that it is no better developed in winter than in summer, and that it is not "tucked up" in warm weather, to cool the intestines, nor spread out in cold weather to make them more comfortable; for which reasons he differs in opinion with Cuvier. That children (who are equally, if not more exposed to starvation than adults,) never have fat in large quantities in the omentum; wherefore he disagrees with Dr. Rush. The Professor looks upon *fat* as an "*unessential* circumstance," in the structure of the omentum.

M. Spallanzani assures us, that among the dormice which were caught for his experiments, some were fat and some were lean; and that they were equally susceptible to the action of cold. From which M. Reeve concludes, that the accumulation of fat is "an *accidental circumstance.*"

But M. Cornish, on the other hand, found, by actual experiments, that dormice and bats, by a hibernation of a fortnight, lost from five to seven grains of weight.—*Daines Barrington's Miscel.* p. 167.

M. Saissy examined the fat of certain hibernating animals, and found that it was soft and unctuous, like that of a hog; that it was inodorous and had an insipid taste. That torpidity effected no material change in it, only imparting a little more consistence. After many interesting experiments, made, apparently, with great care and skill, he delivers his opinion, that "fat has nothing, directly or indirectly, to do with torpidity."

Notwithstanding these high authorities, I am of opinion that the fat of hibernating animals is not "an accidental circumstance," and that it *has* to do with torpidity.

I will, with great respect, give my reasons for this opinion in another part of this essay, where they will be better understood.

3. *The Structure of the Heart of Animals which become Torpid.*—M. Carlisle was of opinion that in hibernating animals there is a peculiar structure of the heart and its principal veins, viz:

1. That the superior cava divided into two trunks—the left passing over the left auricle of the heart and opening into the inferior

*. The very learned and accomplished Doctor Warren, of Boston, is of opinion that the use of the omentum, about which there has long been a difference of opinion, was to afford a soft cushion for the sensitive intestines, to prevent them from being put in pain by pressure within and without; and that it might also serve as a reservoir of fat as a substitute for food when the animal is not in a state to digest. In fevers and consumption, the fat is taken up by the absorbent vessels.—*Observations when this paper was read in Boston.*

part of the right auricle, near the entrance of the vena cava inferior.

2. That the veins, usually called azygos, accumulate into two trunks which open into the branch of the vena cava superior on its own side of the thorax.

3. That the intercostal arteries and veins are unusually large.—*Croonian Lec. Philos. Trans.* 1805.

M. Reeve admits the accuracy of these descriptions, but makes no explanation.—*Essay on Torpidity*, p. 37.

M. Saissy found that the heart, and the arteries, and veins of their thorax and abdomen, (except those of the lungs,) have a greater than ordinary capacity.

4. *Of the Brain of the Animals which become Torpid.*—M. Mangili found but a small number of arteries in the hibernating mammals which he dissected, and those were of small calibre. This deficiency, he concluded, joined with exterior causes of debility, *diminished the energy of the fibres of the brain*, producing first, sleep, and eventually lethargy.—*Regne Animal*, V. 3, p. 121.

M. Spallanzani suggested that the cause of their torpidity was a *repletion of the vessels of the brain.*

While M. Saissy says, that he examined the brains of several of these animals, while they were in a state of profound torpor, and that none of the vicera presented the least indication of apoplexy; but, on the contrary, their vessels were in a state of demi-vacuity and that the blood therein did not appear to move.

5. *Of the Lungs of Animals which become Torpid*—M. Saissy found that the lungs of hibernating animals have a greater capacity than ordinary.

The lungs of reptiles are two capacious membranous sacs, occupying a considerable portion of the visceral cavity, which, as there is no diaphragm, is not divided into thorax and abdomen as in the mammalia. These sacs are divided into numerous polygonal cells. *The trachea is not divided into bronchial ramifications, but terminates abruptly in the pulmonary cavity;* hence the respiration is imperfect, compared with that of birds and the mammalia. Besides which, the batracians have *no ribs*, and in the chelonians the bones of the thorax are so consolidated as not to assist in breathing. The os hyoides and muscles of the throat are substituted, forming a sort of *bellows*, by which the air is forced into the lungs.—*Jones' An. King.* 566.

6. *Of the Nerves of Torpid Animals.*—M. Saissy found that the nerves of the exterior of the bodies of hibernating animals are larger than ordinary.

7. *Of the Blood of Animals which become Torpid.*—M. Saissy found that their blood has a physical property, which distinguishes hibernating animals from all others, of warm blood, viz: *that it*

preserves its fluidity as long as it remains in its proper vessels, notwithstanding it loses its natural heat and mobility.

In their ordinary state, the temperature of their blood is almost as elevated as that of man and analogus animals; but when they become torpid it descends to 37°, 36° and even 35° of F. *yet it remains fluid!*

He also discovered, by chemical analysis, that their blood contains more oxygen and gelatine and less fibrine and albumen than ordinary.

He was of opinion, that this preservation of its liquidity by their blood was attributable to its containing two-thirds less fibrine, one-half less albumen, and one-quarter more water, and a small portion more gelatine than ordinary.

He observes, that from a comparative examination of the blood of many classes of animals, he had come to the conclusion that its concretibility depends upon the quantity of oxygen and fibrine that it contains—and this, he adds, was the opinion of M. Fourcroy, one of the most celebrated chemists of Europe.

M. Saissy is certainly correct; and I think, that from this, his explanation of the blood of hibernating mammals, we may learn the cause of the accumulation of fat in torpid animals. This connection between the blood and fat, escaped the vigilance of this distinguished physiologist, and has not been noticed by any of his successors who have discussed the subject, so far as I have been able to discover.

If the blood of these animals possesses less fibrine and albumen than that of others, then does it possess less carbon and less oxygen; for both fibrine and albumen contain these substances in their composition, and carbon and oxygen enter largely into the composition *fat*. Fibrine has fifty-four parts in a hundred of carbon, and albumen has fifty-six parts in a hundred of carbon, and fat has seventy-eight parts in a hundred of carbon.

Fibrine and albumen have each twenty-two parts in a hundred of oxygen, and fat has nine per cent. of oxygen.

Is it not, then, reasonable to suppose that a portion of the carbon and oxygen which is in the chyle of torpid animals, but which does not enter into their blood, serves to compose the fat, of which we are assured they, not unfrequently, have a superabundance.

From the twenty-two parts of oxygen usually in the fibrine, deduct two-thirds for that quantity that the blood of hibernating animals have less of that constituent, say, - - - 14: $\frac{1}{3}$
And from twenty-two parts of oxygen usually in the albumen, deduct one half for that quantity that their blood has less, say, - - - - - - - - - 11:

and you have, - - - - - - - - - 25: $\frac{1}{3}$
per cent. of oxygen to enter into the composition of fat.

Blood contains a certain amount of fibrine, varying from ·2 to ·9, and chyle contains not more than from ·02 to ·04; fibrine is, therefore, obviously formed in the active metamorphosis of the blood; and that portion which pre-exists in the chyle is modified and rendered more plastic. It is a well known fact, that the respiratory process not only increases the plasticity of fibrine in the blood, but also its quantity, and that, on the other hand, the amount of fibrine diminishes in blood, which is not efficiently brought in contact with oxygen.—*Simon's An. Chem.* 134.

Blood, upon analysis, generally yields several millionths parts of fat; [*Elemens of Zool.* 19; *and see Simon's Chem. of Man.* 142 and 271;] and *that* fat must be the product of the same elements as fibrine and albumen, viz: carbon and oxygen. In some diseases the blood is found loaded with fat.—*Liebig's An. Chem.* p. 92.

In page 103 of Simon's Animal Chemistry, is the following:—"The blood of frozen and apparently dead frogs remains fluid, and the same is the case with hibernating animals, in which the temperature of the blood is reduced to that of cold-blooded animals."

Upon this singularly erroneous paragraph, I beg to be permitted to make a few remarks:

1. "The blood of *frozen* and *apparently* dead frogs remains fluid."—*Frozen* frogs are not *apparently* but *really* dead, (to use this author's own words,) "the coagulation of the plasma is a consequence of the cessation of the vitality of the blood."—*See* p. 102.

2. "And the same is the case with *hibernating animals*, in which the temperature is reduced to that of cold-blooded animals."—The term hibernating animals, *includes* frogs, yet this passage seems to *exclude* them by comparing the temperature with that of *cold-blooded* animals, to which class frogs belong.

3. If M. Simon by "hibernating animals," meant "hibernating *mammals*," the passage is still erroneous; for if it was intended to say that the temperature of the blood of hibernating mammals, was *generally* that of cold-blooded animals, it is contrary to all experience, which shows that their blood, *when they are in a state of activity*, is equal to that of man and analogous animals;* and if it was intended to lay down a rule that the temperature of the blood of hibernating mammals, *when they become torpid*, is reduced only to that of the cold-blooded animals, it conveys an erroneous idea; for when in a complete state of torpidity, the temperature of the blood of hibernating mammals sinks *below* that of the cold-blooded animals, in their ordinary state.

What this author meant to say, was probably this, "the blood of torpid and apparently dead frogs remains fluid, and the same is

* In page 123, he says the temperature of the human body is 98° 7, and 97° 75, and in page 124 he gives the temperature of the bat at 102° to 106°.

the case with other hibernating animals; the blood of them all, when they are rendered profoundly torpid, being of a temperature below that of the cold-blooded animals in their active state."

Fat is not, then, "an accidental occurrence," as taught by M. Reeves; nor is it correct to say, as M. Saissy has done, without sufficient reflection, that "fat has nothing directly or indirectly to do with torpidity." It is, doubtless, a necessary consequence of the diminution of fibrine and albumen in the blood, that it might remain fluid and preserve the torpid animal from freezing to death.

At the same time, by one of those beautiful arrangements, for which the works of nature are so remarkable, this same fat, through the medium of the absorbing vessels, furnishes matter to supply the place of the nutriment which is necessary to sustain the animal in its ordinary condition.

From all which, it appears that there are, in the anatomical structure and physiology of animals that become torpid, distinguishing features, by which they may be known from the rest of their respective classes, orders, tribes, and genera.

Is there any thing peculiar in the *habits* of animals that become torpid, by which they can be distinguished?

It has been remarked, that quadrupeds, when about to become torpid, *roll themselves into a ball;* but it is acknowledged that they exhibit this habit when about to take their *ordinary* sleep, as well as their *lethargic* one. And it is evident that the position is assumed merely to preserve as much animal surface as possible from exposure to the atmosphere.

But this habit is not confined to the hibernating animals. Some monkeys assume the same position; so do squirrels and other animals of the order of "gnawers," which do not become torpid. This habit cannot, therefore, be relied upon as a *distinguishing* feature. Besides, the tenrec, when about to hibernate, which it does from heat, lies on its back and *stretches out its limbs.*

So that, even admitting that this habit belonged to the torpid state at all, it is confined to that occasioned by cold.

Hibernating bats are found in caves, suspended from the roof, and attached together by their thumbs; but many bats which I have caused to become torpid, drew their limbs up close to their bodies, so as to occupy as little space as possible. And bull-frogs, which I have often put into the torpid state, after contending for a long time with the effects of the cold, finally composed themselves in the same position.

M. Reeve, upon the authority of the former, Doctor Barton, of Philadelphia, asserts, that many animals of *the same species* become torpid in *one country*, and do not do so in *another* of a different climate. There are, they say, many species of animals which hibernate in Pennsylvania and other more northern parts of the

United States, which do not become torpid in the Carolinas and other southern parts of the continent.—*See M. Reeve on Tor.* 75, *and Am. Philos. Trans.* V. 4, p. 121, 1795.

I do not perceive that this remark has been corroborated by subsequent observers, but it is due to the memory of the learned Dr. Barton, to acknowledge that M. Milne Edwards, in speaking of the land-tortoise, says, that they hibernate *in moderate climates.*

So Pliny assures us that, *in his time*, the crocodile of the Nile descended that river as far as the Delta, where it hibernated; whereas modern authors aver that this animal is confined to *Upper* Egypt, and that *there it does not hibernate.*

In France, lizards hibernate, but in St. Croix, where I spent a winter, I never heard of one becoming torpid. And Cuvier, speaking of the Loir's hibernating, says, "this is so much their nature, that the loir of Senegal (mus coupeii) which had probably never experienced lethargy in his native country, fell into it *in Europe*, when exposed to cold."

It was probably this idea, that hibernation [torpidity] depended upon climate, that brought Dr. Barton to the conclusion that torpidity was *not a specific character*, but only an *accidental circumstance;* a position which no one, at the present day, would advance.

Snakes of different kinds, such as the rattle, the black, the king and the garter, hibernate together in clefts of rocks and fissures in alluvial banks, in our south. They are found, not coiled up, but stiff and apparently dead.

In their active state, the rattle and black snake are enemies; so are the king snake and rattle snake, yet they all use the same hibernaculum.—*Dr. Dickerson.*

OF THE CAUSES OF TORPIDITY.

THEY ARE IMMEDIATE AND MEDIATE.

Of the Immediate Causes of Torpidity.—They are, 1st, cold; 2d, heat; 3d, drought; 4th, for want of oxygen; and, 5th, a natural necessity to *repose*, while some change takes place in the organization. This last is called "metamorphosis."

1. *Of Torpidity from Cold.*—The effect of cold upon the nervous system of even our own species, producing a propensity to lethargic sleep, has been long known.

Captain Cook relates, that Dr. Solander, while exploring Terra del Fuego, with Sir Joseph Banks and others, cautioned his companions against this effect of cold; yet he could not *himself* overcome the desire to sleep. Numerous were the instances of loss of

life among the French soldiery, in returning from the memorable campaign to Russia. They were overcome by an *irresistible drowsiness*, during which they were frozen to death.

Even travelers, who have ascended the lofty mountains, and persons who have gone to great heights in balloons, have complained of drowsiness, occasioned by cold.

M. Buffon was of opinion that torpidity in hibernating animals, was owing immediately to a loss of temperature in their blood. M. Saissy confirms this idea, so far as regards the animals he examined, and my experience extends it to reptiles. It may be occasioned, says Saissy, by a violent rigidity of the muscular fibres, and a repletion of the blood vessels of the brain. Take an example, he adds, from our species; we feel cold, and, at first, our *fingers* become pale, then stiff, and, finally, lose all sensibility, so that they may be pricked without causing pain. This phenomena, which the cold effects upon *our* fingers, is produced upon *every external part* of the hibernating animals, owing to the number and large size of the *nerves of their exteriors.*

Insects become torpid from cold, so do the Arachnides. M. Reeve says that they retire when the thermometer descends below 50°; that at 46° they cease eating; that at 36° they require only half the oxygen they did in their ordinary state; that at 32° they cease to respire, and that when the thermometer sinks very low* they cease to undergo their usual transformations.

M. Smellie says that the cricket and house-fly become torpid.—*Phil. of Nat. Hist.* p. 300.

The writer of article "Hibernation," in the American Edition of the Edinburg Encyclopædia, states, that bees become torpid *in small hives*, and that some lepidoptera, who are hatched lately, do so likewise. Bees who wander from their hives late in the fall, or too early in the spring, become torpid, and can be resuscitated by removal to a warm place. (*Dr. Harris.*) Yet, in *large* hives, bees are said to enjoy a high temperature. M. Smellie says that some spiders become torpid from cold.—*Phil. of Nat. Hist.* 300.

2. *Of Torpidity from Heat.*—But torpidity is sometimes occasioned by extreme heat, and there are animals who, we are told, hibernate in hot as well as cold countries. The dipus sagitata, (belonging to the order of rodentia,) becomes equally torpid in Egypt and Siberia.

The tenrec, (belonging to the carnaria and insectivora,) although an inhabitant of the Torrid Zone, passes three months of the year in a torpid state.† Bruguire says that it is during *the greatest heat* that they become torpid. Kirby, in his Bridgewater Treaties upon the Habits of Animals, says, that it is remarkable, and worthy of

* How low is *very low*?

† Regne An. Eng. Trans. V. ii. p. 21, and An. de Sci. V. 20 p. 180.

particular observation, verifying the old adage, that "*extremes meet*," that an approach towards the *maximum* of heat produces sometimes the same effect upon organized nature than an approach towards the *minimum* does. In illustration of this remark, he relates that "between the tropics, in the dry season, (which corresponds to our summer,) *nature seems* to be *influenced by a general torpor;* but as soon as the rainy season (which answers to our winter*) returns, the forests present an aspect of movement and of life; and insects are developed, and keep up an uninterrupted hum and bustle."

In like manner, M. Gough informs us, that the hearth cricket (gryllus domesticus) passes the hottest part of the summer in sunny situations, concealed in the crevices of walls and heaps of rubbish; but that it quits its summer abode about the end of August, and fixes its residence by the fire-side of the kitchen or cottage, where it multiplies its species, and that it is as merry at *Christmas* as other insects are in *dog-days.*†—*Nicholson's Jour. of Nat. Philos. and Chem.* V. xix. p. 162; *and see Elemens de Zoologie*, p. 895, *Grillon Domestique.*

3. *Of Torpidity from Drought.—Of the Moluscous Animals.*—Moluscous animals possess fewer faculties, and their structure is less complicated, than that of the vertebrated animals. Their bodies, which are soft, are generally enclosed in, and are protected by, *shells;* the materials to form which they secrete. They have a digestive tube and white blood, and respire sometimes by lungs, and at others by gills. Their organs of sensation are, when present, extremely simple, and they are sometimes wanting.

M. Smellie says, that *several of the moluscæ* hibernate; but he does not enter into particulars, nor even name the genera or species, as he ought to have done.—*Phil. of Nat. Hist.* p. 300.

The writer of the article entitled "*Hibernation*," in the American Edition of the Edinburg Encyclopædia says, that the *naked* moluscous, who reside on land, retire to holes in the earth, or the roots of trees to hibernate. That land-testacea, such as belong to the helix, bulimus, and pupa, not only retire, but make an operculum or lid for the shell, to exclude the air, [cold.]

M. Gough shut several specimens of the garden snail (helix hortensis and helix zonaria) up in a perforated box, secluded from food and water, but not from the air, and they retired in their shells, closing the apertures of them with a thin membrane. There they remained, apparently dead, [torpid from drought,] one of them for nearly three years, until revived by being put into water of the temperature of from 70° to 72°.‡

* Hibernus, from hyems, winter, from the Greek voss quod nempe pluvias fundat; because it pours forth rains.—*Richardson's Dict.*

† There is another kind of cricket, which is called by the French "grillon de champ," that sings all summer.

‡ When he put them into bottles and corked them, they died.

The moluscous animals form two grand divisions, viz: those that have a distinct head, and those that have not. The first of these divisions is separated into three classes, the last, called GASTEROPODES,* contains nine orders. It is the "*gasteropodes pulmones*,"† both the terrestrial and aquatic, that furnishes the hibernaters.

The respiratory system of the snail (which belongs to the gasteropodes) consists of a capacious chamber of a somewhat triangular form, placed beneath the dorsal surface of the body, and separated from the visceral cavity by a broad muscular septum. Into this chamber, through a wide orifice placed upon the right side of the body, near the margin of the shell, the atmospheric air enters. The roof of this cavity is covered with blood vessels, in which the blood is freely exposed to the action of the air.

2. *Torpidity from Drought among the Radiated Animals.*—All organized bodies are composed of solids and liquids. Solids are necessary to preserve the *form* of liquids and to ensure *nutritive* movements. By simply drying a tendon, it diminishes in volume, loses its pliability and smooth appearance, and becomes hard, rigid, translucent and brownish colored. By soaking in water, which it rapidly absorbs, it recovers, in a measure, its former qualities. The amount of liquid in an organized body is much more than one would at first suppose. The body of a man contains $\frac{9}{10}$ of its weight of liquid. In general, liquids predominate in proportion to the *simplicity of animal organization.*

A medusa, weighing five or six pounds, will dry away to as many grains, leaving a transparent cellular matter as delicate as a cobweb.—*Jones' An. King* 65.

After what has been said, the general observer will not be surprised to learn, that the radiated, (which are the most simple animals,) may be rendered torpid *by mere drying;* but he will doubtless be surprised to learn that they *may be resuscitated by moisture merely.*

M. Trembley caused the eggs of a species of tufted polypii to hatch, by putting them in water, after having been kept dry for four months; and he kept the worms of rickety corn for many years dry and apparently dead, [torpid from drought,] and then made them move as well as ever, by barely wetting them with water.—*Spall. Dis.* V. ii, 51, 1780.

M. Spallanzani resuscitated animalculæ that had remained torpid from dryness twenty-seven years. The wheel animal, or rotifer, the sloth, the eel of tyles, and those of blighted corn, by becoming quite dry, lose, to all appearances, life, and may be kept in that state an indefinite time and resuscitated by moisture.

* From gaster, the belly, and pous, a foot.

† The pulmobranchiate gasteropodes of Jones.—*See An King.* p. 403.

4. *Of Torpidity for want of Oxygen.*—M. Edwards tells us, that insects consume a considerable quantity of air compared with their volume, and that they sink into asphyxia when deprived of oxygen; but that when in that state of *apparent death* [torpidity for want of oxygen] they can remain a very long time without losing the faculty of coming to life again.—*Elemens de Zoologie*, p. 853.

I am inclined to the belief, that what is commonly called "*drowned* flies," comes under this category.

5. *Of Torpidity, to enable the subject to effect some natural change of organization, whether of developing some old organ, or making the addition of a new one.*—The torpor under which these changes are effected, is generally termed a *metamorphosis*, and belongs to the class of "articulated," which is divided into insects, the arachnides, crustaceous, cirrhopodes, and annelides. The three first hibernate.

Of Insects.—Nine out of the twelve orders of insects undergo a metamorphosis; but to different extents.*

They also have among them, species that become torpid from heat, and others from cold, and others again for want of oxygen, as before noticed. Some spiders undergo a sort of metamorphosis, for they are born with *three* pair of feet only, and afterward have *four;* whether they become torpid or hibernate for that purpose, I do not know.

Among the *crustaceous*, crabs and lobsters undergo a *partial torpidity* when they renew their shells.

Reaumur, who watched the progress in the craw-fish, (*Astacus fluviatilis*,) says, that towards the commencement of autumn, the animal retires to some secluded position, where it remains *without eating*, during which time its old shell becomes gradually detached, and a new soft cuticle is formed underneath.†—*Jones's An. King.*, 326.

Of the Mediate Causes of Torpidity.—The late eminent Doctor Benjamin Rush was of opinion, that *perfect animal life* included motion, sensation, and thought; that life *might* exist without thought or sensation, but not without *motion*. He further believed, that this motion (and consequently *life*) was *not inherent in body;* but that it was *the effect of stimuli*. That in the absence of *motion*, there was only a *capacity for life*. He supposed that *hibernating animals*, (where, apparently, there was an absence of the stimuli of heat, exercise, and the motion of the blood) life was supported.

1st. By an accumulation of excitability.

* Fabricius distinguishes five kinds of metamorphosis.—*See Jones' Animal King.*, 288.

† Crabs in this state form the "Soft-Crab" of the table.

2d. By the stimulus of the aliment in a state of digestion in the stomach, or by the stimulus of the aliment restrained from digestion by cold.

3d. By the constant action of air upon their bodies.

He adds, that it is *possible* that life may exist in animals, during their hibernation, *in the total absence of impression and motion of any kind.—Lec. on An. Life, Philadelphia*, 1799.

But it has been proven, 1st, that their organs of relation are all paralyzed, that sensibility is null, and irritability nearly annihilated. 2d. That they have no digestion, nor does any food remain in the stomach; and 3d, that they can remain torpid *without air.*

M. Saissy ascribes the torpidity of hibernating mammals, principally to three causes, viz:—

1st. To the greater number and larger size of the nerves of their exterior.

2d. To the comparatively large size of the blood vessels of their thorax (except those of the lungs) and of the abdomen.

3d. To the physical quality of their blood, viz:—its preserving its *fluidity*, however *cold* and *stagnant* it may become.

Of the Mediate cause of Torpidity in Reptiles.—M. Saissy's observations upon the causes of torpidity, are confined to the *mammalia;* let us now see whether the causes of torpidity in *reptiles* is susceptible of explanation.

We are assured that the origin of animal heat, is "the chemical action which the elements of food and the oxygen of the air mutually exercise upon each other." But *reptiles*, in their most active state, eat, comparatively, very little;—they, for the most part, swallow their food *whole*; and, probably, they experience no pleasure in, and consequently have little desire for, eating Indeed, with the serpent, it may possibly even be a source of *pain;* for one lobe of his lungs descends lower in the abdomen, and is there pressed upon by the food which he swallows whole, and in a large quantity, so that it sometimes causes even a *temporary torpidity.*

The *respiration* of reptiles is not a *spontaneous* operation of nature, but it requires a *muscular exertion*, similar to swallowing, to *force* the air into their lungs. They, consequently, possess less power of generating heat, and are properly called "cold-blooded animals."

Their blood contains only five or six hundredths of its parts in weight of globules, and it is well known that there is a remarkable coincidence between the number of globules of blood and the degree of animal heat. Their system is, therefore, predisposed to, and prepared for, a state of torpidity; into which they naturally

and easily sink, by lowering, in a very small degree, their already degraded temperature.

To a tortoise, who, in its most active state, can remain for months without food, the transit to complete torpidity involves a very small degree of change in organic action.*

The Mediate Cause of Torpidity in Insects.—When insects become torpid from cold, it may be explained, at least in part, upon the principles which govern the lethargy of reptiles and mammals. But when they hibernate *for the purpose of metamorphosis* it differs very materially. While the functions of mammals and reptiles, during their torpidity, appear to be *entirely suspended*, those of insects, retiring for metamorphosis, are in the *greatest state of activity*, preparing, under cover of an envelope, new organs of greater perfection, to be used by the animal when awakened from his partial death-slumber to enjoy a brief but more perfect existence.

For this *super-production*, it cannot be said that "they are continually supplied with materials from the more than abundant accumulation of nutrition for daily waste," for they eat nothing, they drink nothing, and, therefore, they have no "continual supply" for even that "daily waste." From what storehouse, then, is drawn the materials necessary to achieve this wonderful transformation? Can no one tell?

Yes, the comparative anatomy of the caterpillar and the butterfly has answered the question in the most beautiful and satisfactory manner.

The whole body of the former is filled with a peculiar fatty tissue, called by entomologists, the "rete epiploon, or fatty-mass." This material, found in great abundance in mature and well-fed larvæ, is enveloped in a most delicate cellulosity, [peritonæum,] and is no doubt the product of former digestion, and stored up for the use of the animal during its pupa state, thus serving the same purpose that the fat in the omentum of the hibernating mammals does during their state of torpidity.—*See Jones' An. King.* p. 296.

Is any thing required in corroboration of this explanation? If so, it is found in the *fact* that in the butterfly, which immediately succeeds, *all the fatty matter has disappeared*, leaving nothing behind but the dense cellular web in which it had been deposited.

So that if, in a previous part of this essay, I proved that chyle was transformed into fat, I have *here* shown that fat is transformed into organism.

* A rattle snake lived more than two years in the Philadelphia Museum, totally deprived of food.—*Harlan's Researches*, 504. But quare if this power of abstinence is not confined to the adult animal, for I found that young growing frogs would uniformly starve to death in forty-eight or sixty hours.

We are now better able to understand the case of the female bear mentioned by Cuvier, and referred to in page 18.

May not, then, this torpidity of insects for metamorphosis be justly considered as a phenomena of the most extraordinary character, well worthy of notice in this enlightened age, and in this inquiring country, of persons of the most exalted talents; and were it for this consideration alone, that I had brought the great subject of Animal Torpidity (even in this bas relief form) before this learned institution, may I not hope for pardon for having occupied so much of their valuable time in reading this imperfect essay.

NOTE.

In page 6, line 9, for "Vespertillo," read "Vespertillio."
Same page, for "genera," read "genus," wherever it occurs.